

and oceans, the hot interior of the earth (geothermal energy), and biomass (agricultural and industrial wastes, municipal solid waste, energy crops) to produce electricity, fuels, and heat—hold significant potential for reducing GHG emissions in the next century by displacing fossil-fuel-generated electricity or petroleum transportation fuels. This potential is shown in the table below and is compared with the business-as-usual carbon projections in Fig. 2.11.

Estimated carbon emissions reductions (MtC/year)			
	2010	2020	2030
Total renewable energy	30–60	75–130	135–260

Assumes successful technology development and subsequent marketplace adoption without significant policy changes.

All regions of the United States have renewable resources of one type or another. Renewable resources currently account for about 8 to 10% of the energy consumed in the United States; most of this is from hydropower and traditional biomass sources. Solar, wind, and geothermal technologies are cost-effective today in small and niche markets, which are important steps to full commercialization.

- In the electricity sector, renewable power avoids emission of about

2.4.4 Renewable Energy

The Potential for Reduced Emissions

Renewable energy pathways—using energy from sunlight, wind, rivers

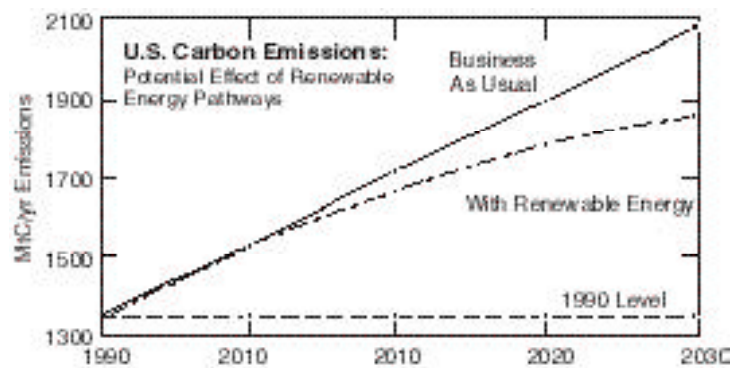


Fig. 2.11. Renewables have the potential for significant reductions of U.S. carbon emissions.

70 MtC per year at the present emissions rate of 0.17 MtC/TWh for electricity.

- Renewable energy technologies are well along a path of decreasing cost (Fig. 2.12), making their expanded commercialization prospects very realistic for early in the next century.
- A level of 20% use in 2025 and 50% use in 2050 is foreseen for the world in a number of projected energy scenarios from, for example, Shell Petroleum Limited (1996), the World Energy Council, and the International Panel on Climate Change (1995). A group of U.S. environmental organizations has also projected the future uses of renewables in the United States in a just-released report, *Energy Innovations* (1997).

Each of the renewable energy technologies is in a different stage of research, development, and commercialization; and all have differences in current and future expected costs, current industrial base, resource availability, and potential impact on GHG emissions. Appendix B describes each of these aspects of the various technologies.

While today's renewables are usually more expensive than the conventional competition on a first-cost basis, they are cost-effective in certain niche markets, especially on a life-cycle-cost basis. Several technologies produce electricity from renewable sources; those nearing commercialization face common problems such as difficulty in obtaining capital, uncertainties related to future electric utility restructuring, and current competition from natural gas. Those technologies further from commercialization need more emphasis on R&D, from fundamental research to resolution of process scale-up issues.

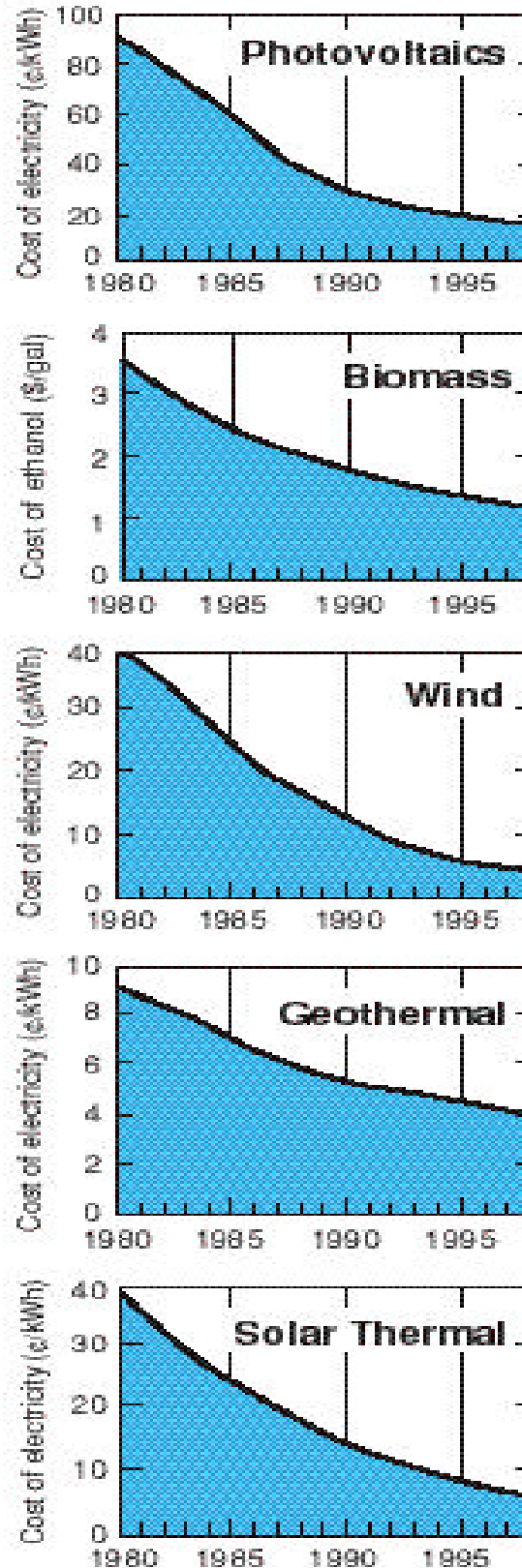


Fig. 2.12. Renewable energy technologies are well along a path of decreasing costs.

Technology Pathways and Opportunities

Biomass Electric refers to technologies that generate electric power from such biomass resources as cofiring biomass with coal, using biomass as the sole fuel in new power plants, or gasifying biomass to replace natural gas. From now through 2010, new biomass electric technologies (including landfill gas) are likely to be commercialized and should have a strong impact on CO₂ emissions. Biomass cofired with coal could also replace a significant portion of coal in electricity production in the near term. Biomass gasification could have a major impact in the forest products industry during the next 10 to 15 years, when many existing boilers will be replaced. RD&D challenges include resolving issues around ash chemistry and NO_x reduction, demonstrating long-term operation of gas turbines on synthesis gas, improving materials, developing sufficient energy crops for feedstocks, and demonstrating advanced technologies.

Wind Energy systems today are very close to being cost-competitive, on a levelized cost basis, with projects at \$0.04 to \$0.07 per kWh; nearly 1800 MW are installed in the United States, and another 6000 MW in other nations. High-quality wind resources are available in 34 of the 50 states and could provide major carbon offsets before 2010. Technology challenges to achieve lower cost and increased reliability include further advances in the understanding of wind flow, aerodynamics, structural dynamics, advanced power conversion devices, and development of durable and lightweight structural components. In the near term, up to 10 to 20% of a region's electrical capacity could be from wind power without any adverse

operating or economic effects. Larger market penetrations in the mid to long term would require addressing the impact of the variation of wind through modification of systems operation, hybrids with other technologies, energy storage, transmission and infrastructure, and improved wind forecasting.

Studies on the effects of avian-wind turbine interactions have shown that when wind turbines are properly sited in areas of low avian usage (away from high resident local populations and migratory flyways), then bird fatalities are negligible.

Hydropower currently generates 10% of the nation's electricity, but generation is declining. Current technology often has adverse effects on fish and downstream water quality and quantity; the goal is to generate electricity without these adverse effects. R&D challenges include quantifying the biological response of fish affected by hydropower projects, modeling the forces inside turbines to predict stress levels on fish, and demonstrating the cost-effectiveness of retrofits.

Solar Photovoltaic (PV) technology uses semiconductor-based cells and modules to directly convert the energy of sunlight to electricity. PV can be used to produce electricity on almost any scale, depending only on how many PV modules are connected together. About 100 MW of PV modules were sold in 1997; annual growth has been 15 to 20%. Hundreds of U.S. applications are currently cost-effective for off-grid electric power needs, such as powering remote telecommunications installations and utility sectionalizing switches. International interest is also very high. PV costs are currently too high for bulk power generation, but costs are decreasing rapidly. Goals are to

compete for peak power shaving by 2010, then daytime utility electricity by 2020. RD&D challenges including improving the fundamental understanding of materials and processes to provide a technology base for advanced PV options, optimizing cell and module materials and design, scaling up cells to product size, validating performance in outdoor and accelerated conditions, and improving manufacturing processes.

Geothermal Energy technologies use energy from within the earth to produce electricity or provide heat for industrial processes. Geothermal heat pumps use the thermal mass of the earth as a heat sink for air-conditioning and heating. Hydrothermal reservoirs produce about 2100 MWe in the United States and about 6000 MWe worldwide. In the United States, direct-use applications produce about 400 MWt; heat pumps produce 4000 MWt and are increasing by 25% per year. Only a small fraction of the huge geothermal resource can be used economically today. With research and policy support, electricity production could be doubled, and thermal production (including heat pumps) could be tripled or more. Geothermal RD&D challenges include improved methods for predicting reservoir performance and lifetime, innovative low-cost drilling technologies, new concepts to expand the use of the resource, improved energy conversion through thermal and fluids science and modeling, and lowering costs through thermal science and process chemistry.

Solar Thermal Electric and Buildings includes technologies that concentrate the heat of the sun to generate electricity or use the heat directly. Solar thermal electric technologies have been successfully demonstrated in nine commercial plants (354 MW)

operating in California. Using existing, relatively conventional technology, including unique cost-effective storage, hundreds of additional megawatts of peaking power could be on-line by 2005; and evolutionary R&D improvements will allow bulk power market penetration by 2020. Solar hot water systems are commercially available, and ventilation preheat systems using unglazed transpired collectors have made significant progress in commercial/industrial markets. RD&D challenges include improving performance and lifetime and reducing manufacturing costs with improved designs and manufacturing technologies, and addressing commercialization challenges similar to those facing wind energy.

Biomass Transportation Fuels include methanol, ethanol, and hydrogen, which can displace petroleum in internal combustion engines. Biomass sources, including agricultural and other wastes, energy crops, and microalgae, are converted to fuels through biotechnology methods (using microbes) or through thermochemical processes. R&D goals are to demonstrate a biomass waste-to-fuels process with an industrial partner by 2000 and larger-scale production and conversion technologies by 2005. By 2010, energy crops should begin to be available, allowing biofuels to compete with petroleum for direct fuel replacement. R&D challenges include low-cost production of enzymes, development of microorganisms for consolidated processes, improved performance of thermochemical processing, and advances in energy crop productivity, cultivation, and harvesting. Biomass transportation fuels are also discussed in Transportation Sect. 2.3.3.

Solar Advanced Photoconversion

technologies use the energy of sunlight to directly produce fuels, materials, chemicals, and electricity from renewable sources such as water, CO₂, and nitrogen. Most of these technologies—involving photobiological, photochemical, and photoelectrochemical approaches—are in the fundamental research stage where technical feasibility must be demonstrated. Examples of these natural and artificial photosynthesis processes include producing hydrogen from water or biomass and producing biodiesel, methane, and methanol from water, waste, and CO₂.

Collateral Benefits

A significant increase in the use of renewable energy pathways would provide benefits beyond reducing GHGs, such as lessening the reliance on foreign oil (especially biomass for transportation fuels), contributing little to waste storage or safety problems, and reducing pollutants. Renewable resources are widespread around the world, are highly attractive to developing countries, and represent a huge potential market for U.S. companies.

Technical Risks and Other Issues

The technical risks vary among the pathways, but there are clear R&D paths to address these risks. Overall, ecological and human health risks are low. Commercial, regulatory, and economic risks are generally moderate to high. In many cases, first costs are higher than for conventional energy choices, while the benefits of renewables do not currently motivate and reward private investment. Mechanisms are required that acknowledge the public value of renewables and help to attract private capital to develop these technologies.

Small renewable energy companies in the United States face very strong international competition. Finally, decisions made under utility restructuring will have a major impact on market penetration for renewable electricity technologies.

Supporting R&D is needing in a variety of basic science and crosscutting areas, such as photosensitive materials, innovative semiconductors, corrosion-resistant and higher-temperature materials, biotechnology, catalysts and separations systems, sustainable agriculture, sensors and controls, electrical components, and computational modeling. A wide range of energy storage and transmission systems—along with the production of hydrogen as transportation fuel—would broaden the opportunities for the deployment of intermittent renewable energies, such as wind, solar photovoltaic, and solar thermal electric.

Strategy and Recommendations

Eventually, the private sector is likely to complete the development and commercialization of renewable energy technologies. But well-considered and sustained government investments, both in the underlying R&D and in actions that will remove deployment barriers, are critical. This is the most important step in realizing the full potential that renewable energy pathways can contribute to reducing carbon emissions early in the next century.

Significant investment would be required from both the private and the public sectors. Currently, the annual federal investment is about \$250 million for these pathways. Increased federal investments to reduce carbon emissions would also return additional environmental

benefits and the opportunity for U.S. companies involved in the area to be key players in the \$1 trillion global energy market and the \$400 billion market for environmental technologies.